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SUMMARY OF INVENTION

In accordance with preferred embodiments of the invention, methods and apparatus are provided for treating materials which have broad advantages over prior systems and a very wide range of applications, including materials processing, wafer processing, medical instrument sterilization, and the like). The method entails forming an ozone-solvent solution at a first temperature having a dissolved ozone concentration and reacting the ozone-solvent solution with the material at a second temperature which is higher than said first temperature. In a preferred mode the reacting step comprises heating at least one of the ozone-solvent solution and the material, thereby causing said ozone-solvent solution to have a higher dissolved ozone concentration while reacting with the material than if the ozone-solvent solution had been formed at the second temperature. Various apparatus are presented to carry out these treatment processes.

For example, in a preferred embodiment of the invention, a system is provided for treating a substrate with an ozone-solvent solution which comprises a supply of an ozone-solvent solution formed at a first temperature which delivers a generally continuous supply of the ozone-solvent solution at the first temperature. The system includes a heater coupled to receive the ozone-solvent solution at the first temperature from the supply and heats the ozone-solvent solution received, and provides a generally continuous supply of heated ozone-solvent solution. The systems also includes an applicator fluidly coupled the heater to receive the generally continuous supply of the heated ozone-solvent solution, the applicator having an outlet configured to direct the heated ozone-solvent solution at a second temperature greater than the first temperature toward a substrate.

Outlined below are some of the advantages the various processes, and how they are achieved:

Higher oxidation rate: provides a method for oxidizing materials using a solution of ozone gas dissolved in solvent which can produce much higher oxidation rates than can be achieved by current methods;

Environmentally benign chemical: provides a method for oxidizing materials at high speed which uses an environmentally benign, residue free chemistry thereby reducing chemical disposal cost;

Increased user safety and reduced chemical cost and reduced chemical disposal cost: provides a method for oxidizing materials at high speed where the oxidizing chemical can be created and destroyed at the point of manufacture thereby increasing user safety, reducing chemical cost and reducing chemical disposal cost;

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Additional chemicals can be injected with minimal impact on dissolved ozone concentration or injected-chemical concentration: provides a method for oxidizing materials using a solution of ozone gas dissolved in a solvent which may include injecting additional chemicals which significantly reduce the time available for injected chemicals to react with the ozone-solvent solution and thereby minimizes any decrease in dissolved ozone concentration or injected chemical concentration caused by such a reaction;

Different injected chemicals may be added to the ozone-water solution during different phases of the materials processing cycle: provides a method for oxidizing materials using a solution of ozone gas dissolved in water which may include a means to select the mix of chemical(s) that are dispensed onto the surface of the materials to be oxidized during a given phase of the materials processing cycle;

DI water and other chemicals may be introduced in lieu of the ozone-water solution during different phases of the materials processing cycle: provides a method for oxidizing materials using a solution of ozone gas dissolved in water which may include a means for injecting chemicals or DI water in lieu of the ozone-water solution and thereby provide a means to selectively dispense chemicals or DI water onto the surface of the materials to be oxidized during a given phase materials processing cycle.

Wafer Processing Advantages

Higher removal rates: provides a method for removing photoresist, post ash photoresist residue, post-etch residue, and other organic materials from semiconductor wafers, flat panel display substrates, and the like which can produce much higher removal rates than can be achieved by current methods;

Lower process temperature and lower corrosion potential: provides a method for removing photoresist, post ash photoresist residue, post-etch residue, and other organic materials from semiconductor wafers, flat panel display substrates, and the like which can produce much higher removal rates at lower temperatures than can be achieved by current methods and thereby reduce the potential for metal corrosion;

Practical throughputs in both single wafer and batch processing systems: provides a method for removing photoresist, post ash photoresist residue, post-etch residue, and other organic materials from semiconductor wafers, flat panel display substrates, and the like which can achieve practical throughputs in both single wafer processing systems and batch wafer processing systems;

Readily retrofitted at low marginal cost: provides a method for removing photoresist, post ash photoresist residue, post-etch residue, and other organic materials from semiconductor wafers, flat panel display substrates, and the like which can be readily retrofitted at low marginal cost to many existing single wafer and batch wafer spin processing tools;

Readily integrated into a cluster tool: provides a method for removing photoresist, post ash photoresist residue, post-etch residue, and other organic materials from semiconductor wafers, flat panel display substrates, and the like which can be readily integrated into a cluster tool comprising multiple processes in a single platform;

Readily integrated with a spin rinse and spin dry step: provides a method for removing photoresist, post ash photoresist residue, post-etch residue, and other organic materials from semiconductor wafers, flat panel display substrates, and the like which can be readily integrated with a spin rinse and spin dry step provides the basis of a dry-in dry-out cleaning process;

Low cost processing chamber: provides a method for removing photoresist, post ash photoresist residue, post-etch residue, and other organic materials from semiconductor wafers, flat panel display substrates, and the like which does not require that high concentration ozone gas be introduced into the process chamber thereby significantly reducing the cost of the wafer processing chamber;

Increased user safety: provides a method for removing photoresist, post ash photoresist residue, post-etch residue, and other organic materials from semiconductor wafers, flat panel display substrates, and the like which does not require that high concentration ozone gas be introduced into the process chamber thereby significantly increasing user safety;

Reduced corrosion potential: provides a method for removing photoresist, post ash photoresist residue, post-etch residue, and other organic materials from semiconductor wafers, flat panel display substrates, and the like which does not require that high concentration ozone gas be introduced into the process chamber thereby eliminating high concentration ozone gas as a source of corrosion;

Nitrogen blanketed process chamber: provides a method for removing photoresist, post ash photoresist residue, post-etch residue, and other organic materials from semiconductor wafers, flat panel display substrates, and the like in which an inert gas such a nitrogen can be introduced into the process chamber;

Increased user safety: provides a method for removing photoresist, post ash photoresist residue, post-etch residue, and other organic materials from semiconductor wafers, flat panel display substrates, and the like in which the dissolved ozone concentration quickly falls to

very low levels immediately downstream of the point of application thereby further increasing user safety;

Medical Instrument Sterilization Advantages

Higher sterilization rates: provides a method for sterilization of medical instruments at moderate temperatures which can achieve much higher sterilization rates than can be achieved by current methods;

Residue free sterilant: provides a method for sterilization of medical instruments at moderate temperatures which utilizes a residue free sterilant and thereby eliminate the risk of carry-over of sterilant chemical residue to the patient and reduce the cost of chemical disposal ;

No water rinse required: provides a method for sterilization of medical instruments at moderate temperatures which utilizes a residue free sterilant and thereby eliminate the need for a separate water rinse step;

Increased user safety and reduced chemical cost and reduced chemical disposal cost: provides a method for sterilization of medical instruments at moderate temperatures in which the active component is created for each cycle and then destroyed at end of the cycle thereby increasing user safety, decreasing chemical cost, and decreasing chemical disposal cost;

Lower consumables cost: provides a method for sterilization of medical instruments at moderate temperatures which has a lower consumables cost (\$.50 per cycle) than leading processes;

Single-use sterilant always at full concentration: provides a method for sterilization of medical instruments at moderate temperatures which is a single pass design in which sterilant is sprayed onto instrument surfaces and then sent to the drain thereby eliminating the degradation in the sterilant concentration otherwise caused by the retention in the sterilant solution of serum and other organic residue washed from the processed instruments;

Low cost sterilization processing chamber: provides a method for sterilization of medical instruments at moderate temperatures which does not require that high concentration ozone gas be introduced into the process chamber thereby significantly reducing the cost of the wafer processing chamber;

Increased user safety: provides a method for sterilization of medical instruments at moderate temperatures which does not require that high concentration ozone gas be introduced into the process chamber thereby significantly increasing user safety;

Reduced potential for instrument materials degradation: provides a method for sterilization of medical instruments at moderate temperatures which does not require that high concentration

ozone gas be introduced into the process chamber thereby eliminating high concentration ozone gas as a source of corrosion of metals or degradation of elastomers or plastics;

Reduced potential for instrument materials degradation: provides a method for sterilization of medical instruments at moderate temperatures in which an inert gas such as nitrogen can be introduced into the process chamber thereby eliminating high concentration ozone gas as a source of corrosion of metals or degradation of elastomers or plastics;

Increased user safety: provides a method for sterilization of medical instruments at moderate temperatures in which the dissolved ozone concentration quickly falls to very low levels immediately downstream of the point of application thereby further increasing user safety;

Applicable to complex shaped instruments with internal passages with large L/D: provides a method for sterilization of medical instruments at moderate temperatures which can be used with complex shaped items, or items containing internal surfaces, such as rigid and flexible endoscopes with internal passages with a large length to diameter ratio L/D.

BRIEF DESCRIPTION OF DRAWINGS

The various features of the present invention and its preferred embodiments may be better understood by referring to the following discussion and the accompanying drawings in which like reference numerals refer to like elements in the several figures.

Fig. 1 illustrates a functional block diagram of a method of processing materials: A cold ozone-water solution at temperature T_1 is heated to temperature $T_2 > T_1$ using a liquid to liquid heat exchanger just upstream of the point of application of the ozone-water solution to the material to be processed.

Fig. 2 illustrates a functional block diagram of a method of processing materials: A cold ozone-water solution at temperature T_1 is heated to temperature $T_2 > T_1$ using a point-of-use heater just upstream of the point of application of the ozone-water solution to the material to be processed.

Fig. 3 illustrates a functional block diagram of a method of processing materials in which additional chemicals are injected into the ozone-water solution just upstream of the point of application.

Fig. 4 illustrates a functional block diagram of a method of processing materials with multiple chemical injection supplies.

Fig. 5 illustrates a block diagram of a method of processing semiconductor wafers with a single-wafer spin processor.